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EP 0395572 A US 5407022 A US 5287936 A
US 5282512 A US 4848476 A

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(54) Earth boring bit with rotary cutter

(57) An earth-boring bit has a bit body 13 and at least one cantilevered bearing shaft depending inwardly and downwardly from the bit body. A cutter 21 is mounted for rotation on the bearing shaft and includes a gauge surface 31 and an adjacent cutter backface 33. The cutter has negative offset with respect to the axis and direction of rotation of the bit. A plurality of cutting elements 19, 41 are arranged on the cutter including a plurality of gauge cutting elements 41 on the gauge surface of the cutter. At least one of the gauge cutting elements projects beyond the gauge surface and defines a cutting surface facing the backface of the cutter for engaging the sidewall of the borehole being drilled as the gauge cutting element moves up the sidewall.

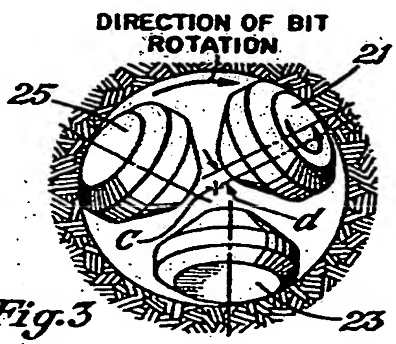

Fig.3

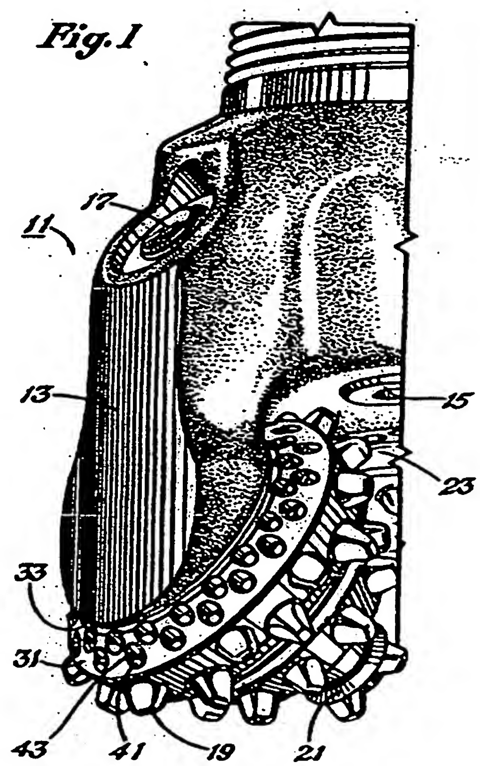

Fig.1

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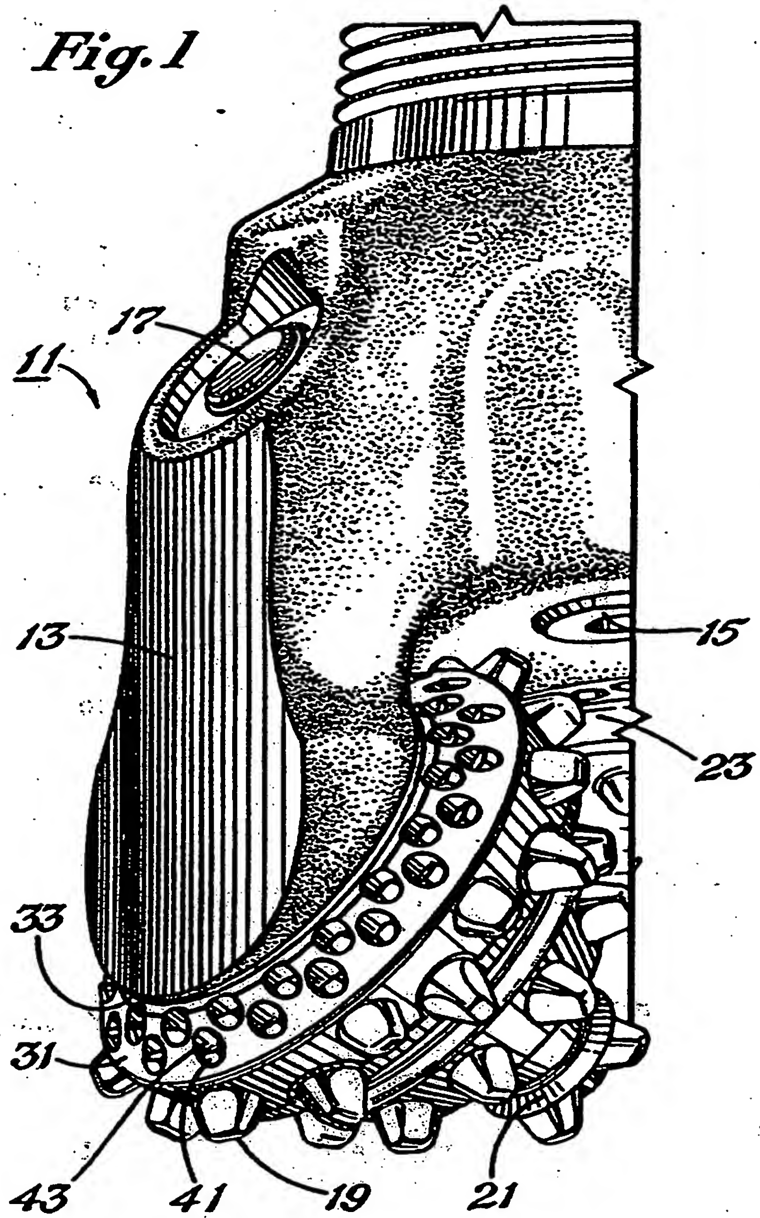

Fig.1

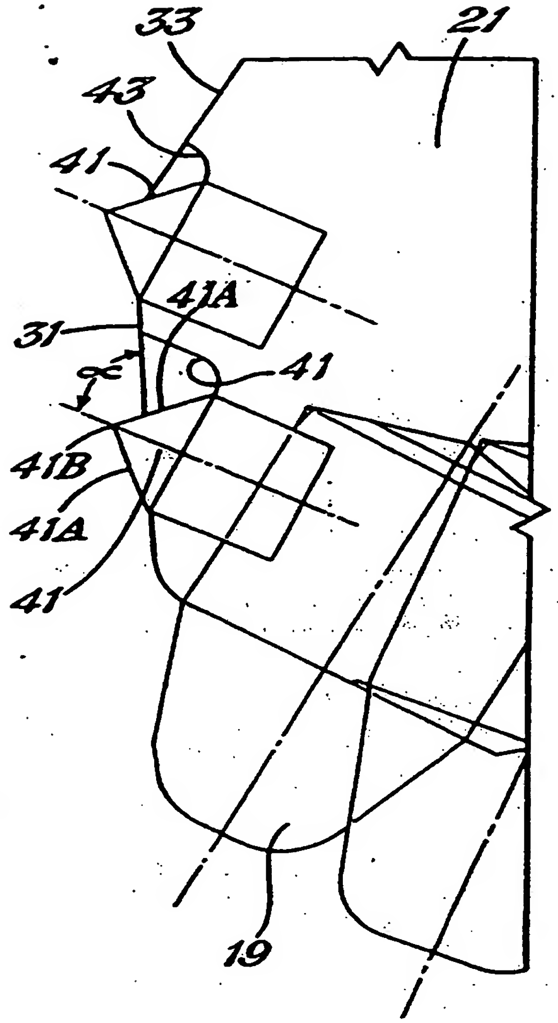

Fig.4

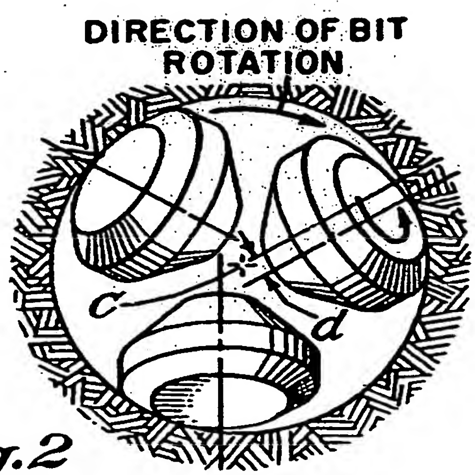

Fig.2

PRIOR ART

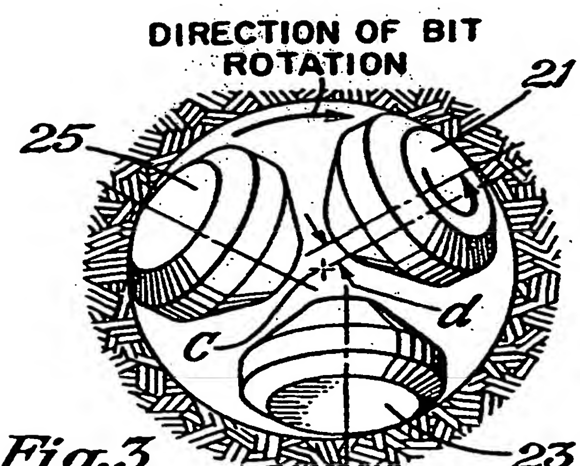

Fig.3

EARTH BORING BIT WITH ROTARY CUTTER

The present invention relates to earth-boring bits with a rotary cutter.

The success of rotary drilling enabled the discovery of deep oil and gas reservoirs. The rotary rock bit was an important invention that made rotary drilling economical.

Only soft earthen formations could be penetrated commercially with the earlier drag bit, but the two-cone rock bit, invented by Howard R. Hughes, US-A-930759, drilled the hard caprock at the Spindletop Field near Beaumont, Texas, USA, with relative ease. That venerable invention, within the first decade of this century, could drill a scant fraction of the depth and speed of the modern rotary rock bit. If the original Hughes bit drilled for hours, the modern bit drills for days. Modern bits sometimes drill for thousands of feet instead of merely a few feet. Many advances have contributed to the impressive improvement of rotary rock bits.

In drilling boreholes in earthen formations by the rotary method, rock bits fitted with one, two, or three rolling cutters are employed. The bit is secured to the lower end of a drillstring that is rotated from the surface or by downhole motors or turbines. The cutters mounted on the bit roll and slide upon the bottom of the borehole as the drillstring is rotated, thereby engaging and disintegrating the formation material to be removed. The roller cutters are provided with teeth or cutting elements that are forced to penetrate and gouge the bottom of the borehole by weight from the drillstring. The cuttings from the bottom and sidewalls of the borehole are washed away by drilling fluid that is pumped down from the surface through the hollow, rotating drillstring and are carried in suspension in the drilling fluid to the surface.

The form and location of the cutting elements upon the cutters have been found to be extremely important to the successful operation of the bit. Certain aspects of the design of the cutters become particularly important if the bit is to penetrate deeply into a formation to effectively strain and induce failure in more plastically behaving rock formations such as shales, siltstones, and chalks.

It is a conventional practice with earth-boring bits of the rolling cutter variety to offset the cutters of the bit such that the rotational axis of each cutter is offset from and does not intersect the geometric centre of the bit. Offset cutters do not engage in a pure rolling action on the bottom of the borehole, but slide and scrape, enhancing the ability of the cutting elements to induce strain in the formation material and increasing the rate of penetration. In most bits with offset cutters, the cutters are "positively" offset with respect to the geometric centre and direction of rotation of the bit. In positive offset cutters, the rotational axis of each cutter is offset from the geometric centre of the bit in the direction of rotation of the bit.

One difficulty encountered in drilling with earth-boring bits of the rolling cutter variety is known as "off-centre" running and occurs when the bit engages in lateral movement and begins to rotate about a point other than its geometric centre. Off-centre running occurs frequently in drilling applications in which the material being drilled is behaving plastically and lateral movement of the bit is facilitated due to lack of stabilization, light depth of cut, high RPM, and low weight on bit. Another factor encouraging lateral movement of the bit is inadequate bottom hole cleaning, which leaves a layer of fine cuttings on the borehole bottom, which acts as a lubricant between the bit and formation material to make lateral displacement of the bit easier.

Cutters with positive offset have a tendency to roll and slide in a direction tangent to the diameter of the borehole and thus generate a force that tends to urge the bit into off-centre running. The cutting elements on conventional roller cone bits are arranged in distinct rows on two or more cutters. The rows are not in the same radial position on each cutter to allow for intermesh of the cutting elements and maximum cutter and bearing diameter. When the bit is running on centre, the rows of the cutting elements align to give full coverage across the borehole bottom profile.

In the off-centre running mode, two or more rows of cutting elements align to give double coverage on some parts of the borehole bottom, leaving others without any cutting action. In this case, rings of uncut material form on the bottom, which have to be disintegrated by the smooth cutter shell surface rolling over it.

The off-centre drilling mode with conventional cutting structures is thus highly inefficient and results in penetration rates that are a fraction of the on-centre mode, for which the drill bit is designed. In addition, the relatively soft steel cutter shell is subject to accelerated wear, which can lead to accelerated cutting structure wear or failure in abrasive formations. Also, the inefficient drilling modes generates more heat, which has an adverse effect on bearing life.

A need exists, therefore, for earth-boring bits having improved ability to resist off-centre running, rather than inducing it.

It is a general object of the present invention to provide an earth-boring bit of the rolling cutter variety with improved resistance to inefficient and harmful off-centre running and this is achieved by the invention set out in claim 1.

According to the preferred embodiment of the present invention, the cutting surface of the gauge cutting element defines a negative rake angle with respect to the sidewall of the borehole.

According to the preferred embodiment of the present invention, the gauge cutting element projects beyond the gauge surface, is chisel-shaped and defines a crest and a longitudinal axis. The chisel-shaped element is tilted toward the cutter backface such that an acute angle of between 15 and 75 degrees is defined between the longitudinal axis and the gauge surface.

An example of the invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a fragmentary perspective view of an earth-boring bit according to the present invention.

Figure 2 is a schematic plan view of the cutters of a conventional or prior-art earth-boring bit, viewed from above.

Figure 3 is a schematic plan view, similar to Figure 2, depicting the cutters of the earth-boring embodying the present invention, viewed from above.

Figure 4 is a fragmentary section view of a portion of a cutter of the earth-boring bit embodying the present invention.

Bit 11 comprises a bit body 13, which is threaded at its upper extent for connection into a drill string. At least one nozzle 15 is provided to discharge drilling fluid pumped from the drill string to the bottom of the borehole to cool bit 11 and carry away cuttings. A lubricant pressure compensator system 17 is carried by bit body 13 to reduce pressure differentials between drilling fluid in the

borehole and the lubricant provided for each of the cutters and its associated bearing and seal.

A plurality of cutting elements 19 are arranged in circumferential rows on a plurality of, in this case three, cutters 21, 23 (one of which is not shown in Figure 1). Cutting elements 19 preferably are formed of a hard metal, such as sintered tungsten carbide, and are secured in apertures in cutters 21, 23 by interference fit. Cutters 21, 23 are frusto-conical and are mounted on cantilevered bearing shafts depending inwardly and downwardly from bit body 13. Each cutter 21, 23 includes a conical gauge surface 31, which is adapted to contact the sidewall of the borehole during drilling operation. Each cutter 21, 23 also includes a cutter backface 33 at the base of the cutter, which is a surface generally perpendicular to the axis of the cutter.

A plurality of chisel-shaped inserts 41 are disposed in counterbores 43 in gauge surface 31. As described in greater detail with reference to Figure 4, gauge cutting elements 41 engage and disintegrate the sidewall of the borehole. Counterbores 43 provide an area in which cuttings can move around cutting elements 41, permitting them to be flushed up the borehole by drilling fluid.

Figure 2 is a plan view of the cutters of a conventionally 5 offset earth-boring bit, viewed from above. The rotational axis of each cutter is offset, in the direction of rotation of the bit, a selected distance d from a parallel radial line intersecting the geometrical centre C of the bit. With this positive offset, the gauge surface of each cutter engages the sidewall of the borehole at a point forward (in the direction of rotation) of the rotational axis of each cutter. Thus, any gauge cutting elements on the gauge surfaces of positively offset cutters engages the sidewall f the borehole as the gauge surface is turning downwardly into the corner of the borehole.

Because the vertical component of the reaction force exerted by the formation material in opposition to the gauge cutting elements is upward, the overall weight-on-bit is diminished, aggravating off-centre running tendencies.

Figure 3 is a schematic plan view of cutters 21, 23, 25 of the earth-boring bit according to the present invention, viewed from above. Each cutter 21, 23, 25 is provided with "negative" offset, in which the axes of rotation of the cutters are offset a selected distance d from a parallel radial line intersecting the geometric centre C of bit 11 in a direction opposite that of the rotation of the bit. For a 20cm bit, the preferred offset is 4.8mm. Provision of all cutters 21, 23, 25 with negative offset moves the cutters on a path skewed towards the centre of the bit, which largely eliminates the tendency of positively offset cutters to run off-centre, while maintaining the advantages of sliding induced by offset. Provision of cutters 21, 23, 25 with negative offset moves the point of contact of the gauge surface of each cutter with the sidewall of the borehole behind the axis of rotation of cutters 21, 23, 25. Thus, the gauge cutting elements (41 in Figure 1) on the gauge surface (31 in Figure 1) will engage the sidewall of the borehole as the cutters turn upwardly with respect to the corner of the borehole. Because the vertical component of the reaction force exerted by the formation material in opposition to the gauge cutting elements is downward, the overall weight-on-bit is increased, reducing off-centre running tendencies.

Figure 4 is an enlarged, fragmentary section view of cutter 21 of earth-boring bit 11 depicted in Figure 1, and illustrates a preferred gauge cutting structure. Chisel-shaped gauge cutting elements 41 are secured by interference fit in a plurality of staggered counterbores 43 on gauge surface 31. Chisel-shaped cutting elements 41 define a pair of flanks or surfaces 41a, which converge to define a crest 41B, which is aligned with the longitudinal

axis of the cutting element. Gauge cutting elements 41 project beyond gauge surface 31 and are tilted toward cutter backface 33 such that an acute angle α is defined between the longitudinal axis and gauge surface 31 of between 15 and 75 degrees. Chisel-shaped gauge cutting elements 41 preferably are formed of cemented tungsten carbide in the configuration described in our US-A-5351768.

One of flanks 411 of chisel-shaped cutting element 41 is arranged to be a cutting surf ace having a negative rake angle (cutting surface leads crest or cutting edge 41B) and facing backface 33 of the cutter for engaging the sidewall of the borehole being drilled as the gauge surface moves up the sidewall. This type of cutting structure is particularly adapted to the negative offset of cutters 21, 23, 25 and is referred to as "inverted" because of the orientation toward cutter backface 33. The cutting surface may be formed of a super-hard material to increase its wear-resistance and to create a self-sharpening element. Furthermore, engagement between gauge cutting elements 41 and the sidewall of the borehole on the upward rotation of each cutter 21, 23, 25 generates a downward force on bit 11, further increasing its ability to resist off-centre running especially in light weight-on-bit drilling applications. Other gauge cutting structure may be suitable, provided that a cutting surface is defined generally facing cutter backface 33 to engage the sidewall of the borehole during the upward rotation of gauge surface 31.

A principal advantage of the present invention is that an earth-boring bit is provided that counteracts off-centre running tendencies and associated low penetration rates and premature wear or failure of cutting structures and bearings.

CLAIMS

1. An earth-boring bit comprising a bit body, at least one cantilevered bearing shaft depending inwardly and downwardly from the bit body, a cutter mounted for rotation on the bearing shaft and including a gauge surface and a cutter backface, the cutter having a negative offset with respect to the axis and direction of rotation of the bit, a plurality of cutting elements arranged on the cutter, including a plurality of gauge cutting elements on the gauge surface of the cutter, at least one of the gauge cutting elements defining a cutting surface facing the backface of the cutter.

2. An earth-boring bit as claimed in claim 1 wherein at least one of the gauge cutting elements projects beyond the gauge surface for engaging the sidewall of the borehole being drilled as the gauge cutting element moves up the sidewall.

3. An earth-boring bit as claimed in claim 2 wherein at least one of the gauge cutting elements is chisel-shaped and defines a crest and a longitudinal axis, the chisel-shaped element being tilted toward the cutter backface such that an acute angle of between 15 and 75 degrees is defined between the longitudinal axis and the gauge surface.

4. An earth-boring bit as claimed in any one of the preceding claims wherein the cutting surface of the gauge cutting element defines a negative rake angle with respect to the sidewall of the borehole engaged by the gauge cutting element.

5. An earth-boring bit as claimed in any one of the preceding claims comprising a pair of said cantilevered bearing shafts.

6. An earth-boring bit as claimed in any one of the preceding claims comprising three said cutters on three said bearing shafts.

7. An earth-boring bit as claimed in any one of the preceding claims wherein the cutting elements are formed of cemented tungsten carbide interference fit into apertures in the cutter.

8. An earth-boring bit as claimed in claim 1 substantially as herein described with reference to the accompanying drawings.

The Patent Office

10

Application No:	GB 9618854.5	**Examiner:**	Martin Holt Riley
Claims searched:	1-8	**Date of search:**	23 October 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F FFD, FFH

Int Cl (Ed.6): E21B

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0395572 A	(Hughes Tool Company)	1
A	US 5407022 A	(Baker Hughes Inc.)	1
A	US 5287936 A	(Baker Hughes Inc.)	1
A	US 5282512 A	(Besson) - see figure 2	1
A	US 4848476 A	(Reed Tool Company) - see figure 3	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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